Design Of A Network Management System For B-ISDN

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1 Introduction

The Broadband ISDN will carry a variety of traffic that will vary over a wide range of salient characteristics. Average bit–rates will range from very low, for certain data services, through a mid–range for voice and medium–speed data, up to multi–Mbits/s for highspeed data and video. The ratio of peak bit–rate to average bit–rate will also vary markedly for these various categories of service.

The Quality of Service required by different traffic classes will also show wide variation. Voice and video signals, for example, can tolerate packet loss, but not packet delay, whereas most data services can tolerate packet delay, but not loss.

It should be possible to market different Qualities of Service to customers, thus offering them a choice as to the standard service they wish to purchase. Customers who transmit traffic that carries a high intrinsic value may choose to pay a premium for the smallest possible probability of access denial and packet loss.

To control Fast Packet Switching nodes, fast decisions need to be made due to the high transmission speeds of the optical links. Network Management needs to be built into the design of B-ISDN to ensure that constraints upon the delay/loss of data are met. On the other hand, a network–wide view is essential to ensure that the network is maintained close to optimal performance.

Our proposal offers a solution to these problems, by considering the optimization of the network as a fundamental action in the working of the B-ISDN, and providing a fast means of implementing control actions.
2 Overview Of Proposal For Network Management Of B-ISDN

2.1 Objectives

The overall objective of Network Management schemes is to obtain the best possible performance from the available resources in the network under all conditions. The criteria for determining the “best” performance will be defined as a matter of policy. Dimensions included are: service to customers in emergency circumstances, revenue to the network operator, service to customers under normal commercial conditions (the customers pay for the service they want). These dimensions are typically in conflict, and the determination of what is meant by “best performance” resolves that conflict by edict.

This paper does not offer any judgements on the best way to set a particular set of objectives in any given circumstances. By way of illustration, it might be determined that the appropriate objectives for a particular circumstance are:

1. To provide the guaranteed level of service to premium customers and services,
2. Subject to satisfying (1) above, to maximise revenue, and
3. Subject to satisfying (1) and (2) above, to maximise service to non-premium customers and services.

2.2 Architecture And Implementation

The proposed method of Network Management relies heavily on the concept of virtual paths [1]. A Virtual Path (or VP) is a fixed path through the network connecting a source to a destination. Thus each alternative route for an origin-destination pair corresponds to a different virtual path. Our proposed method of Network Management is to be implemented in a two-strata architecture: Traffic Management Stratum and the Traffic Control Stratum. This is a subset of the general Network Management Strata proposed in [2]. The Traffic Management Stratum will have available information from all the parts of the network and will determine quotas for all traffic flows (call attempts, bursts and packets). These quotas will apply to the various types of traffic on each VP and would represent the optimal (as determined by the objectives discussed earlier) flows in the network. Due to the size of the network, the Traffic Management Stratum will be broken into a hierarchy of Traffic Managers. The Central Traffic Manager (CTM) will have the duty of optimizing the global performance of the network, with Regional Traffic Managers (RTM) concentrating on the local behaviour of a region of the network. The traffic control stratum will be fully distributed to each resource in the network. Its functions will be, in priority order:

1. Protect each local resource from overload, and,
2. Ensure that the traffic carried on each VP matches the quotas determined by the traffic management stratum (as far as possible, while meeting the primary function of overload protection).
These functions would be implemented by a Local Controller resident at each node. The fast speeds of transmission make it necessary that all decisions made by the Network Control Stratum require no processing. Any decisions will be made by either consulting a look-up table [2] or performing a hard-wired function. Feedback Flow Control will be used to maintain the current traffic as close as possible to the desired quotas, and this will be discussed more in Section 2.3.

The means of communication between the different strata is not defined in this paper. Control signals to and from exchanges could be sent on the same network as the data transmitted (as highest priority and on duplicated packets) or on a separate network. The proposed scheme can be modified to handle both possibilities.

Figure 1 shows a diagram of the overall network management facilities and architecture.

2.3 Feedback Flow Control

The purpose of Feedback Flow Control (abbreviated to FFC) is to keep traffic flows as close as possible to the quotas generated by some optimization program in the Network Management Stratum. The idea is to have quotas upon the flow of entities on each VP, and a measure of the actual flows currently in the VP. Each class of traffic (e.g. voice, video or data) and priority of call would have a quota placed upon it. A new call setup would be accepted on a VP if the traffic is less than the quota, and rejected otherwise. Thus the traffic in the network would be kept as close as possible to the optimal values and network performance would be close to a maximum. Feedback (from the current state of the VP) is used in controlling the flow of traffic in the network.

As well as quotas upon the number of calls entering the network, quotas can also be put upon the rate at which entities from currently established calls are entering the network.
This is the same as the *leaky bucket* technique, where a *pseudo-buffer* is placed at the origin of the traffic, and is used to ensure that the incoming traffic never exceeds its given characteristics.

These controls will be placed at the originating exchange of the VP, in addition to the functions of the Local Controller explained in Section 4.

## 3 Resources and Constraints

The functions of the Broadband ISDN will be carried out by three major types of resources:

1. **Intelligence** – the processors and databases that allow for calls to be established, serviced while in progress, and cleared down;
2. **Transmission** – the fibre optic systems interconnecting both switching nodes and resources of type (1); and
3. **Switching** – buffers, switching fabric, and any other resources required for the switching of calls and packets.

Corresponding to each type of resource will be a constraint on the demands that can be served by the B-ISDN. Depending on the technologies used and the engineering of the network, some constraints may never be operative: some resources may be so well provided that scarcity of that resource never prevents service being given immediately. For generality, we will assume that all three types of resources may become scarce from time to time.

Two fundamental principles of Network Traffic Management apply. Firstly, we must ensure that there cannot be an avalanche effect. Secondly, we must make best use of the opportunity to choose under conditions of scarcity.

Following the notation of [2], the network is considered in several conceptual levels:

1. **Exchange Section Level**
2. **Exchange (network node) Level**
3. **Subnetwork Level**
4. **Network Level**

Multiservice traffic flows on the links on the network. The traffic carried by the network is broken into layers.

1. **Packet Layer**
2. **Burst Layer**
3. **Call Layer**
4. Flow Layer

In the two strata system described in this paper, the Traffic Control Stratum makes instantaneous decisions (by hardwired decision or table look up) upon the first three traffic layers and the first network level mentioned above. The Network Management Stratum concerns itself with the other network levels and the other traffic layer. The Network Management Stratum consists of a hierarchy of Network Managers, each attempting to optimize its section of the network, but with increasing scope of view as the hierarchy is ascended.

The details of the operation of each of the two strata are described in the following two Sections.

4 The Traffic Control Stratum

The traffic control stratum is implemented as a distributed system. Local to each resource is a Local Controller which protects the local resource and implements, as nearly as is practical, the quotas determined by the Traffic Management Stratum. The Local Controller will also maintain the integrity of the network should the Traffic Management Stratum fail to function, or if communications from the Traffic Management Stratum to the Traffic Control Stratum are interrupted.

The information available to the Local Controller includes:

1. Information communicated from the Traffic Management Stratum. In particular, quotas for every class of traffic on every Virtual Path that loads the local resource; and
2. Information from the local resource: rate of flow and present state.

We assume that there is insufficient time for the Local Controller to perform significant processing functions. Instead, all of the functions it performs must be implemented as simple operations such as table look-ups and comparisons. The functions it may perform include:

1. Reject or accept items for service.
2. Discard items from service.

Items can be either packets or bursts.

These hardwired actions would be performed when the local node cannot handle the incoming traffic or when the Network Management Stratum issues the appropriate control signal. The priority of the items would be used to determine which ones should be controlled. Assume all input packets to be labelled with not only VP information (Virtual Channel Identification, Virtual Route Number as in [3]), but also information on the priority of the packet, and the type of packet (whether it is part of the burst, and perhaps
the size of the burst). Given this information, a decision can be made as to which control action to perform.

If the buffer is full, and an item (burst or packet) arrives of high priority, then low priority items would be discarded from the buffer. This guarantees service to high-priority services. Rejecting call-setup packets would protect the intelligence of the network from overload. The processor that is working as part of the Intelligent Network (which was maintaining a local data-base or communicating with a global one) would activate this particular control.

If it is known that a link/node is losing packets/bursts regularly, then high priority traffic using that link/node could duplicate the item to be sent, and send it via a different route (e.g. Reroute the duplicated packet/burst). The Network Management Stratum will have to activate this control, as well as setup the table of alternative VPs at the receiving end. Signalling packets might use this control to ensure that a Local Controller receives the control packet. “Flooding” a network with duplicate packets could be used when setting up a network to determine paths through the network from an origin to a destination.

For nodes on the edge of the network, it would be possible stimulate the transmission of packets (e.g. data) when a lull in VP capacity occurs. The converse of this control, retarding the transmission of packets, would be implemented by the leaky-bucket technique described earlier.

**Network Failure Controls.** If the Traffic Control Stratum were to lose communication with parts of the the Network Management Stratum, the Local Controllers involved would assume that a failure had occurred in the Network Management Stratum, and would perform local traffic management controls. This would take the form of flow-control on a link-by-link basis with adjacent nodes to maintain integrity of the local system. If significant loss and delay occurred on an outgoing link, the Local Controller would block call-setups along the link to stop new traffic originating. Flow Control would be enforced by sending control signals back to previous exchanges to reduce traffic. Thus each Local Controller will reject packets on outward links if it receives a control signal from neighbouring exchanges. These messages would eventually be received by origin nodes which would alter quotas, and perhaps limit the length and type of services provided.

We differentiate between nodes on the edge of the network and those not directly connected to customers. Nodes connected to customers will, in addition to the features listed above, implement quotas via the Feedback Flow Control mechanism described earlier. Figure 2 shows a possible implementation of FFC at a node. A table exists for each VP from a node with traffic quotas for each type of traffic in the network. A call-setup procedure uses this table to determine whether the call is to be accepted or not, and if successful, to which VP the call is to be allocated. Calls that are accepted are added to a table of current calls. Subsequent packets sent from that customer would be routed along the same VP. The ability to reroute calls is achieved by changing entries in this table.

5 **The Traffic Management Stratum**

Due to the size of the network, the Traffic Management Stratum will be implemented in a hierarchical structure. Regional Traffic Managers (RTM) will control a region of the
network (e.g. Melbourne CBD and Metropolitan area). A Central Traffic Manager (CTM) will control the overall behaviour of regions and be concerned with global optimization. The decision of a higher layer is passed as a constraint to a lower layer. A diagram of the functional components is shown in Figure 3. The tasks of each are outlined as followed.

5.1 Regional Traffic Manager

The aim of the the Regional Traffic Manager is to optimize the performance of the network in a particular region. Service requirements and policies will be locally determined, with constraints placed upon it by higher layers of Traffic Managers. The main components are:

*Optimizer*

The primary aim of the Regional Traffic Manager is to optimize the traffic flows in its part of the network, given information about the current network state. For example, a Linear Program model, such as that described in [4], could be used to optimize flows throughout the network.

The input to the optimization model would be state data and policy decisions (do we optimize for maximum profit or service?), and the output would be quotas for each traffic class on each of the VPs in the network.

Contrary to [2], the functions of routing and flow-control will not be separate in FFC. The optimal traffic that flows on each VP will be specified by an optimizing routine. Routing...
of calls will be implemented by changing the quotas on one or more VPs.

The number of VPs in the original network would change with shifting traffic patterns. To find VPs initially, a “flood” technique could be used. A control packet is sent out from the origin, and is duplicated onto every outgoing link by all nodes in the network. The packet is modified at each node to indicate the path it took. After sorting at the destination end, the packets received would indicate the shortest paths through the network. The most used VPs would be classed as “active” and used all the time, and the remaining paths would be stored at the origin, so that if expansive routing is ever needed, recomputing paths through the network would not be necessary. A list of most used VPs would be built up over time, and added to or removed from as required.

Any model that can be solved in real-time would involve many approximations and simplifications, and it is to be expected that the quotas output from the optimizer will be inaccurate and sub-optimal. It is important that all quotas be made too big, and modified continuously as explained later.

**Simulation** As previously mentioned, the behaviour of the B-ISDN would be complicated and non-linear. Simulation of the overall behaviour of the network, or detailed simulation of critical parts of it, would be needed to check the behaviour of the network under certain controls before they were applied. The process of optimization, simulation and then revision of results would be continuously performed in the Traffic Management Stratum.

**Communication**

The RTM needs to transmit revised traffic quotas to all origin nodes in the network. As
As this, the current state of all nodes and links will have to be received from the network. The information needed from the nodes will change with time (as we could be using a different model of the network under different conditions). The Communication Unit will perform the task of transferring the state information needed/sent, control signals and quotas to the network. The control signals may be sent on the same network, or on a separate one, and this choice will be discussed later. The RTM would also need to communicate with other RTM’s and Network Managers higher in the hierarchy.

*Data Tracking and Predicting*

The input parameters of the model (the current state of the network) are constantly changing, a tracking and predicting device is needed so that we attempt to optimize the state of the network in some *future* time period, not the present. The type of data needed might also change with time [6], depending upon the optimizing model and the sampling interval. The Data Tracking and Predicting Unit will process and control the gathering of data.

*Exception Handler*

An Exception Handler will govern the behavior of the network under sudden or planned changes. A knowledge base will contain pre-planned information about the correct responses to sudden failure or overload. These responses will be of the form of

1. Revise Network
2. Run the Optimizer
3. Transmit the new controls needed

Revising the network could mean several things. It could entail reconfiguring the network, choosing a different optimization routine, performing post-optimality analysis, changing input data or the data prediction model. Reconfiguring the network could include expansive routing into regions of another network. Such requests would entail communication between RTMs to compare resource and service requirements. The RTM would also alter the controls active on the Traffic Control Stratum, as explained previously. Besides handling sudden changes, the knowledge base would contain history records that will affect the network, e.g. an outage due to maintenance or the gradual increase in traffic that will occur as Christmas Day approaches. The choice of which network model to use for the Optimizer under certain network states would also be processed by the exception handler.

5.2 The Central Traffic Manager

The Central Traffic Manager (CTM) has the task of globally optimizing the network. Its functions would be similar to a RTM (and perhaps there would be opportunities to take on the task of a RTM if a failure should occur) but its main aim would be to look at global issues. These would include policy decisions, conflict of interest between RTM’s and issuing global quotas for VPs. As mentioned earlier, the decisions of a higher layer in the Network Manager Strategy would be used as constraints in the lower layers.

6 Reliability

Our proposed method of management of the B-ISDN relies heavily upon the actions of a Traffic Management Stratum. Reliability would be maintained by having fail-safe quota-tables in each node, and putting sufficient intelligence in the Traffic Control Stratum to control itself independently of the Traffic Management Stratum. If the Traffic Management Stratum should fail, nodes will switch automatically to the back-up tables, which would ensure network integrity, even though it would be running at a sub-optimal performance.

The Local Controller will provide local security by rejecting call-setup requests along a failed link, and by enforcing flow-control along links in the network. Link or node failures can be overcome by rerouting existing calls around the congested area, and setting all quotas on affected VPs to zero.

As mentioned earlier, it is not assumed that the control packets will be sent on either the same network as the data, or on a separate network. In the first case, reliability would be maintained by sending control packets at the highest priority (receiving immediate attention) and by having nodes duplicate the packet via different VPs in the network. Due to the large number of alternative routes in the network, it is unlikely that link failures will isolate a node from the Traffic Management Stratum. The use of an alternative network will increase reliability, as if one network experienced failure, the control signals can be sent on the other. The use of back-up tables and limited intelligence in the Local Control Stratum would make the possibility of catastrophic failure very small.
7 Conclusion

In this paper, a two strata Network Management scheme is proposed for Broadband ISDN. The Traffic Management Stratum has the task of determining from state information the optimal traffic flows in the network, and placing quotas upon each Virtual Path. The Traffic Control Stratum attempts to achieve these traffic flows by Feedback Flow Control, and maintains the integrity of the local environment. Network Management is considered to be a fundamental part of the operation of the future network, as it is needed to both optimize the network’s performance and guarantee service to customers. The proposed method specifies an architecture and implementation which addresses these problems. Further work will be needed in mathematical modelling and simulation of traffic in the B-ISDN to determine the exact nature of the optimization routines and controls implemented by the two strata.

References


